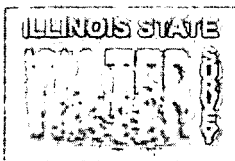


Illinois State Water Survey

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Nitrogen Cycles Project

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Glossary

The **hydrosphere** includes all the liquid and solid water standing and flowing over and through the geosphere. The pools of water that in sum make up the hydrosphere's reservoir are oceans, lakes, rivers, glaciers, aquifers (ground water), and soil moisture. Over 96 percent of the water on earth is in the oceans with the remaining found in freshwater. Glaciers hold 69 percent of the freshwater, 1 percent is in lakes and rivers, and 30 percent is in ground water (Dingman, 1994). The hydrosphere interacts with the atmosphere, geosphere, and biosphere through these pools following a complex and cyclic path commonly known as the Hydrologic Cycle.

Fluxes among the pools and spheres take place through precipitation, condensation, interception, evaporation, transpiration, infiltration, percolation, ground-water flow, spring or seepage flow, advective flow, overland flow, and channel flow. The land surface receives 60 percent more water through precipitation than is transpired and evaporated from it. The remainder produces surface runoff and ground-water recharge. The residence times in continental pools are highly variable: generally averaging a few weeks in river channels, months to years in lakes, reservoirs, and wetlands; weeks to years in soil moisture; and days to tens of millennia in ground water.

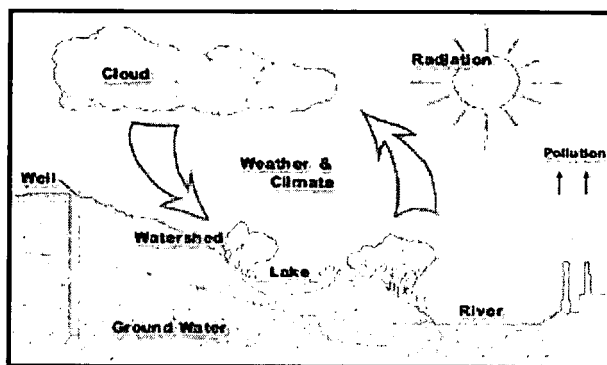


Diagram of the Hydrologic Cycle [Click to enlarge](#)

The hydrosphere is the center of water quality issues and problems. Water is a principal acting agent and primary medium for picking up materials and transporting them from one location to another in large quantities. Hypoxia in the Gulf of Mexico is believed to be an example of such a problem where large quantities of nutrients from nutrient-rich areas are transported by the Mississippi River to the Gulf causing over-enrichment of its waters and subsequent decline in water quality (Goolsby et al., 1999).

Water serves as a solvent and physical/chemical transport medium for many dissolved and particulate materials. The composition of natural water is the result of numerous chemical reactions, including mineral dissolution, that have dissolved material, altered previously dissolved

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components, or materials eliminated from solution by precipitation or other processes (Hem, 1985). These reactions are influenced strongly by biologic activity and physical, chemical, and photo-chemical processes.

The dominant N species in waters are dissolved inorganic N – ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-) –, dissolved organic-N, and particulate organic and inorganic N (Burt et al., 1993). Cumulatively, these N species are reported as total N. In surface waters and riparian wetlands, aquatic vegetation can remove and store large amounts of dissolved N. Dissolved and particulate N in surface waters are measured using standard sampling and laboratory methods for water quality analysis. However, biological N stored in non-planktonic plants and animals is typically not measured as part of the water quality measurements. Some of the challenges in conducting N mass balance studies are determining the unmeasured amounts of N removed from the water and stored in aquatic organisms and sediments, and N added to the water from resuspension, erosion, and dissolution processes.

There are substantial differences in chemical properties among the N species. For example, NH_4^+ cations (positively-charged ions) are strongly sorbed by some mineral surfaces. Anionic species (negatively-charged ions) such as NO_3^- are readily transported in water. NO_2^- and organic-N are unstable in aerated water and, at certain levels of concentration, are considered to be indicators of pollution through disposal of sewage or organic waste. The presence of NO_3^- or NH_4^+ might be indicative of such pollution also, but the pollution could have occurred at a site or time substantially removed from the sampling point (Hem, 1985).

N from the hydrosphere interacts with the atmosphere, geosphere, and biosphere in many different ways. For example, NO_3^- -N in surface waters can diffuse into underlying anoxic water layers or underlying anoxic sediments. In such environments biological activity assimilates some of the NO_3^- -N and denitrifies the rest into N gases. Some of these N gases can be reassimilated by reaction with humic substances and other organic materials. Some of the N_2 gas participates in N fixation and the remainder is emitted to the atmospheric boundary layer as long as the partial pressure remains above the equilibrium values given by Henry's Law.

N concentrations and species in surface and ground waters are determined by environmental conditions in the atmosphere, watershed, water body, ground water and geosphere, particularly precipitation, solar radiation, surface runoff, ground-water flow, pH, temperature, oxygen availability, biological conditions, and the presence and availability of other chemical species important in N dynamics, e.g. phosphorous (P). These conditions can affect the rates of N processing, such as fixation, nitrification, assimilation, denitrification, volatilization, mineralization, and fluxes. Seasonal changes, high flow

events, and diurnal cycles affect temperature and pH which can control N species composition. The processes are determined by the energy needs/losses of these reactions, which must consider the rate of reaction, organic matter availability, partial reactions, energy source, and O_2 availability (Burt et al., 1993). These processes occur in all open freshwater (lakes, streams, rivers) and ground water, but at different rates.

Because most ground water is anoxic, NH_4^+ is typically the most common N species in ground water. The sources of NH_4^+ in relatively deep and some shallow anoxic aquifers can be natural (i.e., N associated with clays and other minerals), but in other shallow anoxic aquifers, the predominant sources of N may be anthropogenic (e.g., landfills, sewage, and septic systems). NO_3^- is usually found only in oxygenated ground water. Because many sources of N to ground water are at or near the Earth surface and NO_3^- is often readily reduced in anoxic ground water, elevated levels of NO_3^- are usually found only in shallow parts of aquifers. For example, Kelly (1997) found NO_3^- -N concentrations of up to 15 mg/L in the top 10 m of an aquifer in Mason County, Illinois, but no detectable NO_3^- at greater depths. The disappearance of NO_3^- at depth was attributed to denitrification. Because N is readily utilized by plants and microorganisms in the soil zone, it is unusual for "pristine" ground water to have greater than 1-2 mg NO_3^- -N/L (Chappelle, 1993). Human activities are usually the source of excess NO_3^- in aquifers where NO_3^- -N concentrations exceed 1-2 mg/L. There are, however, areas where substantially higher NO_3^- -N concentrations in pristine systems occur naturally, due to the oxidation of reduced N compounds in sediments or rocks (Strathouse et al., 1980; Hendry et al., 1984). For example, some wells in the Mahomet aquifer in central Illinois yield water with NO_3^- -N concentrations between 10 and 20 mg/L (Holm, 1995).

There are many potential sources of N to surface and ground waters. Determining N sources in the water bodies is important and complex. N in fresh water comes from watersheds, soils and sediments of the receiving water bodies, from direct deposition of N from the atmosphere, and from N fixation in the water body itself. Available spatial and temporal measurements of N in soils, streams, and rivers are usually sparse. The available data shows significant variability of N concentrations in space and time.

Short (1999) summarized and analyzed N measurements made on 209 stream monitoring stations in Illinois during 1980-1996 as part of Illinois Environmental Protection Agency's (IEPA) Ambient Water Quality Monitoring program. These measurements show mean $(NO_3^-+NO_2^-)$ -N concentrations varied from less than 2 mg/L in most of southern Illinois to 9.9 mg/L in most of central Illinois and some parts of northern Illinois. The values were higher in spring and early summer months and lower

in the fall. Yearly averages were almost consistent during the monitoring period except in the early nineties when the values were higher. Mean concentrations of total ammonia ($\text{NH}_4\text{-N} + \text{NH}_3\text{-N}$) were found less than 0.2 mg/L in most of Illinois except in some northeastern, mid-central, and southern Illinois areas measuring up to 4.15 mg/L, which were mostly associated with wastewater treatment plant discharges. Total Kjeldahl-N (TKN), which is a measure of $\text{NH}_4\text{-N} + \text{NH}_3\text{-N}$ plus organic-N, was collected in 82 stations and the statewide mean was 1.39 mg/L. Individual station means of TKN ranged from 0.27 mg/L on Lusk Creek to 5.77 mg/L on the Calumet-Sag Channel.

Other N measurements in Illinois streams/rivers, tile drains, and soils as part of specific studies are also available in the literature (e.g., Goolsby et al., 1999; David et al., 1997; Demissie et al., 1996; Borah et al., 1999; Mitchell et al., 2000; Roseboom et al., 1982, 1983). Some of these studies show $\text{NO}_3\text{-N}$ concentrations in streams and tile drains as high as 18.8 mg/L (Borah et al., 1999) and 49 mg/L (David et al., 1997), respectively. $\text{NH}_4\text{-N}$ and Kjeldahl-N in soils at streambank erosion sites measured up to 74 mg/kg and 795 mg/kg, respectively (Roseboom et al., 1983).

Ground water in Illinois usually has low concentrations of N. Warner (2000) summarized data from 1984 to 1991 for about 2,500 community water-supply wells in Illinois, with a special emphasis on the Lower Illinois River Basin (LIRB). The median $\text{NH}_4\text{-N}$ concentration in the LIRB was 0.74 mg/L for all wells, and 0.08 mg/L for wells less than 50 ft deep. The median ($\text{NO}_3 + \text{NO}_2$)-N concentration in the LIRB was 0.03 mg/L for all wells, and 0.25 mg/L for wells less than 50 ft deep. The concentrations in the rest of Illinois were similar to the LIRB. Less than 2% of the wells in the LIRB had ($\text{NO}_3 + \text{NO}_2$)-N concentrations exceeding the maximum concentration level or MCL (10 mg N/L), and all of these were shallow wells (< 150 ft deep). NO_3^- contamination, however, is more common in private wells than public wells. Private wells are generally shallower than public wells, mainly found in rural, agricultural areas, and sometimes not well protected from surface contamination. Dug and bored wells, which are common in rural Illinois, are especially susceptible to surface contamination. For example, Schock et al. (1992) found that 40% of dug and bored wells sampled in Effingham County, Illinois, had ($\text{NO}_3 + \text{NO}_2$)-N concentrations exceeding the MCL.

Cited References

Borah, D.K., M. Bera, S. Shaw, and L. Keefer. 1999. *Dynamic Modeling and Monitoring of Water, Sediment, Nutrients, and Pesticides in Agricultural Watersheds during Storm Events*. Contract Report 655. Illinois State Water Survey, Champaign, IL.

Burt, T.P., A. L. Heathwaite, and S.T. Trudgill. 1993. *Nitrate:*

Processes, Patterns and Management. John Wiley & Sons, Inc., New York, Chapters 5 & 10.

Chapelle, F.H. 1993. *Ground-Water Microbiology & Geochemistry*. John Wiley & Sons, Inc., New York.

David, M.B., L.E. Gentry, D.A. Kovacic, and K.M. Smith. 1997. Nitrogen balance in and export from an agricultural watershed. *J. Environ. Qual.*, **26**: 1038-1048.

Demissie, M., L. Keefer, D. Borah, V. Knapp, S. Shaw, K. Nichols, and D. Mayer. 1996. *Watershed Monitoring and Land Use Evaluation for the Lake Decatur Watershed*. Miscellaneous Publication 169, Illinois State Water Survey, Champaign, IL.

Dingman, S. L. 1994. *Physical Hydrology*. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Goolsby, D.A., W.A. Battaglin, G.B. Lawrence, R.S. Artz, B.T. Aulenbach, R.P. Hooper, D.R. Keeney, and G.J. Stensland. 1999. *Flux and sources of nutrients in the Mississippi-Atchafalaya River Basin: Topic 3 Report*. White House Office of Science and Technology Policy Committee on Environment and Natural Resources, Hypoxia Work Group, Washington, D.C.

Hem, J.D. 1985. *Study and Interpretation of the Chemical Characteristics of Natural Water*. Washington, D.C., USGS Water-Supply Paper 2254.

Hendry, M.J., R.G.L. McCready, and W.D. Gould. 1984. Distribution, source and evolution of nitrate in a glacial till of southern Alberta, Canada. *J. Hydrol.* **70**:177-198.

Holm, T. R. 1995. *Ground-Water Quality in the Mahomet Aquifer, McLean, Logan, and Tazewell Counties*. Contract Report 579. Illinois State Water Survey, Champaign, IL.

Kelly, W.R., 1997. Heterogeneities in ground-water geochemistry in a sand aquifer beneath an irrigated field. *J. Hydrol.* 198:154-176.

Mitchell, J.K., G.F. McIsaac, S.E. Walker, and M.C. Hirshi. 2000. Nitrate in river and subsurface drainage flows from an east central Illinois watershed. *Transactions of the ASAE*, **43**(2): 337-342.

Roseboom, D., R.L. Evans, J. Erickson, and L.G. Brooks. 1982. *Appendices for An Inventory of Court Creek Watershed Characteristics that may Relate to Water Quality in the Watershed*. SWS Contract Report 322A, Illinois State Water Survey, Peoria, IL